EXHIBIT 30

Expert Report of J. Keith Nelson, Ph.D.

City of Spokane v.
Monsanto Company, et al.

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PCB FLUIDS IN THE POWER INDUSTRY

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Qualifications

Dr. Nelson has worked in both the power industry and academia on both sides of the Atlantic. After obtaining a Bachelor's degree in Electrical Engineering, he started his career with a UK utility company before returning to the University of London to complete a doctorate on transformer oil insulation. He continued as a faculty member for 10 years undertaking funded industrial research on electrical insulation; particularly transformer fluids. He was responsible for the High-Voltage and Short-Circuit laboratories. In 1979, he moved to the US to take up a position with General Electric as manager of the Dielectrics unit of their Corporate Research and Development Center. In this position, he was responsible for the Company's electric insulation interests which included both transformers and capacitors, and involved close cooperation with the manufacturing facilities. During the latest phase of his career, Dr. Nelson was the Head of the Department of Electric Power Engineering at the Rensselaer Polytechnic Institute in Troy, NY where he maintained close ties with the US power industry, and undertook research on a variety of electrical insulation and materials development initiatives (including dielectric liquids). He is currently a consultant and Emeritus Professor of Electric Power Engineering.

He is a chartered professional engineer, a Fellow of the IEEE and IET, and the recipient of numerous awards. He has published a book on Dielectrics and authored over 250 peer-reviewed papers, patents, and other technical documents. A *Curriculum Vitae* is provided in Attachment 2

TABLE OF CONTENTS

SUMMARY OF OPINIONS

(a) At no point have PCBs been a necessary part of the electrical industry.

(b) In the late 1960s and early 1970s, after PCBs were detected throughout the environment, the electrical power system in the US would not have shut down or have been severely affected had Monsanto stopped PCB sales.

(c) PCB use and application in transformers and capacitors could have been phased out in the 1950s in a similar fashion to the eventual phase out in the 1970s, should Monsanto have announced it would stop selling PCBs much earlier.

(d) It was common knowledge in the electrical industry that some amount of dielectric fluid used in transformers and capacitors would be released into the environment through ordinary manufacture, use, service, and disposal.

A. At no point have PCBs been a necessary part of the electrical industry.

Polychlorinated biphenyls (PCBs) were first manufactured in 1929 [11]. In 1930, General Electric Co. introduced a PCB-treated paper capacitor based on Monsanto's Pyranol 1476[1] [9]. Over the following years, applications and use of PCBs in the electrical industry were further developed and PCBs were extensively used in capacitors and transformers [1] [10].[2] In both applications, PCBs were dielectric fluids that provided electrical insulation. Although PCBs were favored for certain applications because of their non-flammable characteristics and high thermal stability, at all times non-PCB dielectric options existed for capacitors and transformers. [57 pg. 177].

1. PCBs were not necessary for transformers.

Transformers have never required the use of PCB-containing dielectric fluid. [57 page 177]. First, a number of non-PCB dielectric fluids have long existed and were in fact predominant. Second, distribution transformers may be designed without using dielectric fluid at all.

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1 The first two digits in the numbering designate the type of compound and the last two the percentage of chlorine in the structure. The high chlorine content variants are extremely persistent in the environment.

2 Monsanto's PCB dielectric fluids were often actually mixtures of PCB with varying quantities of trichlorobenzene and/or tetrachlorobenzene.

i. Non-PCB Dielectric Fluid

Non-PCB dielectrics have long been used in transformers. Mineral oil has been used in transformers since the first introduction of high-voltage units and is still the predominant fluid today. Even during the period when PCBs were sold by Monsanto, the majority of transformers used mineral oil [23] [48]. The Edison Electric Institute estimated that during that period only 40,000 of the 20,000,000 transformers in the electric utility industry utilized PCB fluid [25]. Furthermore, in 1967, it was reported that 20 of the 61 leading utilities in the US had made decisions to avoid PCB fluids altogether, using conventional mineral oil instead [20]. This was primarily due to the cost of PCB-containing dielectric fluid, which was considerably higher than mineral oil. PCBs in 1967 were about 8 times the cost of mineral oil [20]. The US Environmental Protection Agency indicated that, in 1979, a 1 MVA, 15kV PCB transformer was 40% more expensive than an equivalent mineral oil unit [26].

The majority of power transformers are used outdoors and in industrial or remote locations. Mineral oil is, and always has been, the primary option for such uses. However, in some instances transformers require a dielectric that is less flammable than mineral oil. Although transformer explosions and fires are rare, they do happen, and the use of a dielectric that is less flammable than mineral oil is attractive where transformers are used in close proximity to the public. For example, a less flammable dielectric is desirable when smaller transformer units are housed in residential basements, schools, mines, marine applications, on railroad locomotives, and other sensitive locations.[3] PCBs are considered "non-flammable" and were therefore useful as dielectric fluids in transformers in such sensitive locations. However, at all times when PCBs were manufactured by Monsanto, other dielectric fluids existed for those applications.[4]

[3] However, about 60% of these critical applications are industrial load centers [22] that are seldom located close to personnel.

[4] A comprehensive source for the properties of many candidate fluids (silicones, natural and synthetic esters, etc.) in comparison with naphthenic mineral oil and typical PCBs has been assembled by the United Nations Environment Programme [39].

In the transformer arena, silicone fluids (dimethylsiloxane) have been extensively studied as PCB substitutes and widely used in circumstances when the flammability of an insulating liquid was of paramount importance such as in confined spaces, for example, in building basements or in railroad locomotive applications. Silicone fluids were introduced in the 1940s, and although still flammable, have high flash points, and, out of contact with air, are stable up to a temperature of 250°C [8]. They have loss tangents generally lower than 10^{-4} (which compares very favorably with 10^{-2} for typical PCB fluids) and approximately the same electric strength as PCBs (the electric strength of transformer silicone oil on the basis of the ASTM standard method at 25°C is 30-40 kV, compared to 30 kV for PCB[27]). These fluids make a very acceptable substitute for PCBs in sensitive transformer applications. Compared to PCBs, silicone fluids are also more benign and less likely to dissolve gaskets, O-rings, and other non-metal parts of the transformer. Consequently, silicone-filled transformers do not face the same failure and leakage problems that are characteristic of PCB-filled transformers. The properties, testing methods and application of silicone fluids as dielectrics are well documented [1-4, 9, 17-18]. In the 1970s the first cost of a transformer filled with high fire-point silicone liquid ($8/gal in 1974 [41]) was little different from an equivalent unit utilizing PCBs ($3-4/gal) since the fluid cost is only a small part of the unit cost, and the EPA concluded in 1979 that the switch to silicone fluid would have little economic impact [26]. Silicone oil is a little less efficient as a heat transfer fluid and thus units that are retro filled would be expected to run 3-10°C hotter. This is not an operational problem but may have a small impact on the transformer life.

Fluorocarbons (or perfluorocarbons) represent another category of non-flammable alternatives to PCBs in transformers. These fluids were introduced to the market in the mid-1950s [7] and have better electric strength than PCBs (~30% improvement) and substantially lower losses than PCBs. Detailed comprehensive comparative data has been documented by Clark [27]. However, many of these fluids are very volatile and may persist in the atmosphere; meaning their use would be limited to entirely enclosed applications. In addition, these fluids would have been considerably more expensive than PCBs ($300 per gallon) [26]. Fluorocarbons have been utilized in

more specialized applications, such as airborne uses, where their improved properties such as superior electric strength can justify the substantially increased cost.

Fully biodegradable common vegetable oils have been available for insulating applications for 80 years and are categorized "less flammable" than mineral oil. Although used commercially in capacitors, common application in the transformer context began in the 1990s when ABB (Asea Brown Boveri) introduced its Biotemp® product based on a high oleic oil having an increased oxidation resistance [12,13]. This is now in use worldwide. The cost of Biotemp®-filled transformers was said in 2002 to be 1.25–1.30 times the cost of an equivalent unit filled with mineral oil [15] and thus less expensive than PCBs. Even today, there is substantial interest in natural and synthetic ester liquids as evidenced by the fact that there were 23 papers on these liquids in the recent IEEE International Conference on Dielectric Liquids [24]. This type of vegetable oil dielectric could have been developed well before Monsanto stopped selling PCBs. Both refined natural vegetable oils and also synthetic esters, which can be formulated to counter some of the drawbacks (such as oxidation) of the natural product, were available. Indeed, in the 1970s, I was the external examiner for a doctoral thesis from the University of Madras in India which sought to develop a transformer fluid based on vegetable products.

ii. Transformer designs that do not require dielectric fluid

Although not strictly a PCB substitute, the PCB transformer fleet could have been substituted with dry-type transformers which would have provided a truly non-flammable alternative [48]. Most of the applications where the fire risk cannot be tolerated, and where PCB use was valuable, are in the lower voltage classes. Examples would include the end-use delivery of power to urban apartment blocks, railway locomotives, and mining operations. Dry-type transformers are suitable for these lower voltage classes, and would be acceptable alternatives to PCB-filled transformers. While dry-type units would have been slightly more expensive than PCB-filled transformers, it is germane to observe that Monsanto documented in 1966 that there were 3 times as many dry-type units as Aroclor units serving the non-flammable duty situations [20], and that ratio had been constant for 10 years. At that time it was clear that a majority of users preferred to serve the non-

flammable duty with dry-type transformers, even though dry-type transformers were generally slightly larger than PCB units and could generate more audible noise. This was largely because of explosions linked to PCB-containing transformers. Although PCB units do not catch fire, there have been a number of explosions caused by gas from internal arcs precipitated by moisture. Indeed, in the period 1956-58 there were 12 explosions documented in PCB units which represent a higher incidence than in dry-type units when adjusted for inventory numbers [20].[5] It is also important to recognize that both General Electric and Westinghouse were advocating dry-type transformers as early as 1942 [31].

At the higher voltage levels for which such dry-type units are unsuitable, there have been past initiatives to introduce gas-insulated transformers using sulphur hexafluoride (SF_6) under pressure as an insulant. However, despite the fact that this is an enclosed application, SF_6 is a greenhouse gas which makes it unattractive for widespread application. In the context of this report this situation almost never occurs since such voltage levels are usually confined to remote substations.

b. PCBs were not required for capacitors.

Unlike large power transformers, which have limited distribution, capacitors are ubiquitous throughout the modern world. Although large units are used on power systems for the purpose of power factor correction and voltage control (as a cost effective method of making electric transmission more efficient), the majority of capacitor units are incorporated in single-phase motor start/run applications and in fluorescent lamp ballasts in both the domestic and industrial arenas throughout the world. Indeed, it would be difficult to find a modern household not using such capacitors in appliances.

[5] The issue was sufficiently problematical that GE mounted a research effort to quantify the nature of the gases generated by arcing products of PCBs in the early 1970s [41]. This was done for Aroclor 1016 in laboratory and transformer tests with the finding that gases were moderately explosive in air. Gases generated by arcing in Aroclor 1242 were also indicated by tests conducted by ITE [45].

Although the non-flammable characteristic of PCB fluids was attractive, the small amount of the liquid impregnant in a capacitor does not contribute to the fire hazard in the same way as it does in transformers. As a consequence, capacitor manufacturers did not base decisions to buy Aroclors on the fact that Aroclors were fire resistant [49]. A "less flammable" alternative for PCBs would have always been acceptable, and PCBs were never imperative to the capacitor industry.[6] Even in the case of larger capacitors used in the power system, these are usually located in outdoor fenced substations or pole-mounted on the distribution system so that the need for a totally non-flammable impregnant was never necessary.

At no point were PCBs strictly imperative to the capacitor industry. Mineral oil has long been a viable alternative, as were variants of vegetable origin. Such materials were available as long as PCBs were available [23]. Although modern substitutes do have some advantages, PCBs could have been phased out of the industry in the mid-1940s if, for example, castor oil had been utilized (see timeline in Attachment 1). It is fair to say that the industry viewpoint [30] in the mid-1970s was that adoption of some of the alternatives, although viable, was regarded as a step that could wait until the environmental case became commercially compelling. Indeed, prior to the ban, Monsanto had concluded "that the environmental threat posed by the present usage of PCBs in capacitors is negligible" [30]. However, after the withdrawal of PCB-based fluids, most of the major OEMs (Original Equipment Manufacturer) quickly adopted proprietary alternatives, based generally on mixtures of synthetic materials, which had been readily available for many years and thus could have been developed much earlier without the availability of PCBs. It is pertinent to note that GE was already considering alternatives to replace PCBs in capacitors as early as 1956 [23].

In an effort to replace PCBs in capacitors following their ban, a number of substitute oils have been made commercially available. In the capacitor field, castor oil (an oil of vegetable origin

[6] It is also argued that capacitors can take advantage of the high relative permittivity (dielectric constant) exhibited by PCBs. The relative permittivity of polychlorinated biphenyls is 5-6 which contrasts with a value of about 2.3 for conventional mineral oil. However, this advantage is exaggerated since the fluid is not the main dielectric in a capacitor which is usually polypropylene (or paper in earlier times), but is only used as an impregnating fluid to prevent electrical discharges and so the inventory of fluid is small. Consequently, the advantage is nothing like as large as the 2:1 ratio in the permittivity might suggest.

having a somewhat elevated permittivity and low loss) has been well documented [1, 23]. Many other vegetable oils have received attention as possible substitutes, since, being esters, they are dipolar and thus have higher permittivities attractive for capacitor use. However, many tend to gel on exposure to air and generally none are as stable as mineral oil. Examples of these developments can be found in the Westinghouse "Wemcol®" product (isopropylbiphenyl) or Nippon Oil's "PXE" (phenylxylyl ethane) [3]. The GE product with the trade name "Dielectrol" was originally based principally on dioctyl phthalate, but underwent multiple developments between its introduction in 1977 [32] with the later variants utilizing a mixture of benzyl toluene [28]. Dioctyl phthalate is the most common member of the class of phthalates which were first introduced decades before the 1970s and thus was already readily available [56]; being produced for other purposes (plasticizers) at a price which was competitive with PCBs [29]. [In the mid-1970s, PCB (Aroclor 1016) was about 60c/lb which compared with dioctylphthalate at 30c/lb.] It was identified as a substitute by GE as early as 1973 [40], but clearly could have been used several decades before that. Similarly, it was reported in 1975 that McGraw Edison and Exxon had introduced butylated monochlorodiphenyl and diisononylphthalate respectively as PCB replacements for capacitor fluids [42]. Synthetic hydrocarbons, the best known of which are polybutylenes and dodecyl benzene, also offer possibilities as acceptable substitutes for PCBs. Polybutylenes have electrical properties similar to other pure hydrocarbons and have found uses as cable and capacitor impregnants. Similarly alkyl benzene has properties which make it attractive as a PCB substitute. The constituents of most of these alternative fluids were available commercially many years (sometimes decades) before PCBs were removed from the market. For example, documentation from 1962 shows that several types of polybutylene were available in the US from both the Standard Oil Company and the Oronite Chemical Company [9]. Similarly, dodecylbenzene is a precursor to sodium dodecylbenzenesulphonate, a surfactant widely used as a laundry detergent, and introduced in the 1930s.

B. The United States electrical power system would not have been severely affected had Monsanto stopped selling PCBs once they were confirmed as a widespread environmental contaminant.

In 1966, the existence of PCBs were confirmed in the food chain [11]. Over the following few years, the breadth and severity of the environmental problem caused by Monsanto's PCBs became well-documented [34]. In a presentation to their Corporate Development Committee, Monsanto clearly portrayed the huge environmental consequences [36]. Monsanto took steps to stop selling PCBs for "open uses," such as in caulk and paint, in 1970 and announced its intention to stop selling PCBs from "semi-closed" uses, such as hydraulic fluids, in 1972. [26, 33]. Monsanto, however, did not stop selling PCBs for uses it deemed "closed uses," such as in capacitors and transformers, until 1977 prior to the ban by the US Environmental Protection Agency in 1979 [44]. Monsanto claimed at the time that it had to sell PCBs for use in the capacitor/transformer industry even after stopping sales for other uses because they were under pressure from GE to continue supply for their products [22,38]. Indeed, it is recorded that they (GE) would be willing to have an officer of the Company go on record as stating that the unavailability of these materials would result in serious power blackouts [34] which was the view later taken by others on the basis that there was no viable alternative. However, statements in the literature [5, 11, 19] to the effect that there were (and still are) no known substitutes meeting the essential characteristics of PCBs must be read very carefully in context. Such statements are usually referring to the substitution of a fully non-flammable alternative with acceptable electrical properties, but a totally non-flammable alternative was never really necessary. [57 pg. 161-177]. In other words, GE claimed there was no substitute with the same fully non-flammable qualities as PCBs. While this may have been true, there was never a need for a substitute with the exact same qualities as PCBs.

Even today, fully non-flammable alternatives are not used. Rather, for sensitive applications, the industry utilizes materials that are "less flammable" than mineral oil. These "less flammable" alternatives have existed since the mid-1950s, at the latest. Following the ban on PCBs, the industry has turned to many of these alternative "less flammable" materials and found them to be acceptable. Indeed, General Electric was looking at the use of "less flammable" liquids as early as 1956 [23]. Since most of these were known a quarter century before the PCB ban (see timeline in Attachment 1), the industry could have adapted at a much earlier stage. The insurance industry -- which was a factor in the demand for non-flammable fluids -- adapted and developed criteria to allow "less

flammable" substitutes and specified the necessary safeguards [25]. With the objective of making more use of "less flammable" liquids, discussions on the fire test standards were in progress in the mid-1970s by industry representatives on the standards-making bodies [43]. Statements such as "Lack of availability of PCBs for this equipment (capacitors and transformers) would cause a major and lengthy disruption in the nation's electrical system" made by the government Interdepartmental Task Force on PCBs[11] in 1972 were grossly exaggerated, and, indeed, there were no major disruptions after the ban. The limited penetration (less than 10%) of PCB transformers [3] (see earlier) makes it clear that statements by Monsanto such as "without the availability of Askarel transformers, large cities like NY would be shut down with no power" [22] were false [20].

The reality is (and was) that numerous alternatives could be identified for both the critical transformer and capacitor applications. There were always viable alternatives to the use of PCBs. In the commercial world, cost is always an important consideration. Although, many of the alternative fluids are more expensive than PCBs and the inventory of fluid in a large transformer is considerable, the liquid insulant is only one component of a complex, and often labor intensive, manufacturing process. As a result, alternatives increase the cost of a complete unit by a much smaller factor. This is illustrated in Table 1 taken from reference [16]. If one eliminates fluorocarbons from consideration [since their cost is of the order of ≈US$500 per kg and they are a contributor to global warming], then Table 1 shows projected transformer first costs (without regard to ongoing expense, life, etc.) for the major PCB substitutes in comparison with conventional naphthenic mineral oil shown as the base case in row 1. The size of transformers (500 kVA to 2.5 MVA) depicted in Table 1 is in the range that might be used to supply a large building and thus be a candidate for PCB replacement. The first three cases considered represent three different replacement fluids (all of which have been known for several decades). The last three rows in Table 1 represent cases where the fluid has been eliminated entirely in the transformer design to form a "dry-type" unit as discussed in Section I.

The most expensive solution (but not necessarily the most reliable) is seen to be the encapsulated "dry type" epoxy resin unit having an average cost of about $37/kVA which compares

with the conventional oil transformer having a first cost of about $17/kVA. However, for the units impregnated with alternative fluids, the average cost enhancements are approximately:

High MW hydrocarbons	1.2
Vegetable oils	1.3
Silicone fluids	1.4

TABLE 1
APPROXIMATE FIRST COST COMPARISON

DESCRIPTION	kVA -->	500	750	1000	1500	2000	2500	AVERAGE $/kVA
MINERAL OIL	**$-- 65C rise**	**$13,500**	**$16,000**	**$17,300**	**$19,300**	**$22,500**	**$25,300**	
(FLAMMABLE)-160C	ratio to oil	1	1	1	1	1	1	
	$ / kVA	$27	$21	$17	$13	$11	$10	$16.6
LESS FLAMMABLE	**$--65 C rise**	**$16,200**	**$19,000**	**$21,500**	**$25,000**	**$26,300**	**$27,500**	
HYDROCARBON-308C	ratio to oil	$1.20	$1.19	$1.24	$1.30	$1.17	$1.09	
	$ / kVA	$32	$25	$22	$17	$13	$11	$20.0
LESS FLAMMABLE	**$--65 C rise**	**$17,700**	**$21,000**	**$23,000**	**$26,000**	**$29,200**	**$32,500**	
VEGETABLE -360C	ratio to oil	$1.31	$1.31	$1.33	$1.35	$1.30	$1.28	
	$ / kVA	$35	$28	$23	$17	$15	$13	$21.9
LESS FLAMMABLE	**$--65 C rise**	**$18,900**	**$22,000**	**$24,000**	**$27,300**	**$30,000**	**$34,000**	
SILICONE-330C	ratio to oil	$1.40	$1.38	$1.39	$1.41	$1.33	$1.34	
	$ / kVA	$38	$29	$24	$18	$15	$14	$23.0
DRY TYPE - VPI	**$--150 C rise**	**$15,900**	**$20,000**	**$22,000**	**$26,000**	**$30,500**	**$36,000**	
POLYESTER	ratio to oil	$1.18	$1.25	$1.27	$1.35	$1.36	$1.42	
	$ / kVA	$32	$27	$22	$17	$15	$14	$21.2
DRY TYPE - VPE	**$--150 C rise**	**$19,000**	**$22,500**	**$25,000**	**$32,000**	**$36,500**	**$41,000**	
SILICONE	ratio to oil	$1.41	$1.41	$1.45	$1.66	$1.62	$1.62	
	$ / kVA	$38	$30	$25	$21	$18	$16	$24.8
DRY TYPE - EPOXY	**$--80 C rise**	**$35,000**	**$32,000**	**$35,500**	**$39,000**	**$48,000**	**$57,000**	
FULL CAST	ratio to oil	$2.59	$2.00	$2.05	$2.02	$2.13	$2.25	
	$ / kVA	$70	$43	$36	26.00	24.00	22.80	$36.8

Table 1. Comparison of the first cost of intermediate size transformers utilizing different fire resistant strategies. (after [16])

While the 40% increase in costs for the silicone fluid is substantial, it is obviously not as large as would be expected on the basis of the price differential of the fluid alone. Furthermore, the 20 – 40%

enhancement is still less than some of the dry-type units. When, it is further recognized that fewer than 10% of transformers are involved, the financial impact of ceasing PCB use was manageable.

As explained earlier (Section A2), in the arena of capacitors, the case for continuing PCB sales after they were found widespread throughout the environment was not compelling. The smaller inventory of fluid used in capacitors made the fire risk less critical, and a lower permittivity fluid could be accommodated with a small increase in size. At no point were PCBs really necessary for the capacitor industry[7].

C. It was common knowledge in the electrical industry that some amount of dielectric fluid used in transformers and capacitors would be released into the environment through ordinary manufacture, use, and disposal.

Despite Monsanto's designation of capacitors and transformers as "closed uses" of PCBs, this was an inaccurate and misleading description. It was known in the industry, at the time that PCBs were sold into the capacitor and transformer industries, that PCBs inevitably migrated from capacitors and transformers to some extent. During the time Monsanto manufactured PCBs, it was common knowledge in the power industry that PCBs could enter the environment through use in capacitors and transformers:

(1) PCBs entered the environment during the process of manufacturing transformers and capacitors.

At all times, it was well recognized in the industry that some amount of PCBs would be released into the environment by transformer and capacitor manufacturers. In earlier times, releases to the environment were legal and therefore foreseeable to those in the power industry and some

[7] For completeness, it should be noted that at no point were PCBs necessary for operation of other equipment in the electric power industry. Mineral oil was (and still is) used in significant quantities to insulate circuit breakers (high-voltage switches used in a power system to route power and isolate faulty equipment). Generally, chlorinated aromatics, like PCBs, have not been used in oil-filled switchgear because the presence of hydrogen and chlorine in their structure produces hydrogen chloride when a switching arc is drawn. Similarly, PCBs generally have not been used in oil-filled cables because of the disadvantage associated with the high permittivity, contamination and loss, although it was reported that Pirelli General were looking at the possibility of utilizing Aroclor 1242 in impregnated paper cables [21].

manufacturers took steps to tighten their procedures to limit releases [30, 35] clearly recognizing the environmental issues involved. After 1976, transformer and capacitor manufacturers were required to implement stricter protocols for the handling of PCB fluids. However, leaks and inadvertent discharges were widely known to occur. For capacitors, the nation-wide collectable PCB waste during manufacture/impregnation in the late 1960s has been estimated to amount to 850,000 lbs. per year and scrap totaled 50,000 lbs. annually [22]. It was possible to reprocess good quality Aroclor by distillation, but the economics of doing so were not attractive [22].

(2) It was known in the industry that some amount of PCBs would be released into the environment when used as intended in capacitors and transformers.

It was common knowledge in the power industry during the time Monsanto manufactured PCBs that some amount of PCB capacitors and transformers would fail, resulting in PCBs being released into the surrounding environment. [50 at 422-453].

Regarding capacitors, case damage and concomitant leakage were, and are, inevitable. When a capacitor fails it will sometimes be preceded by a bulging of its case, but unfortunately this is seldom visible since the unit is usually embedded. This means that most capacitor leaks would come without warning. A Monsanto internal document noted that PCB capacitor failure rates in the first year can be as high as 0.1% [23]. Such "infant mortality" is common in many forms of electrical equipment, and after that failure rates drop significantly. However, the lifespan of capacitors is shortened when built closer to their design limits. Monsanto's documents indicate that, as early as 1956, it had information that its customers were building capacitors using PCBs close to their design limits, such that a shorter lifespan for many of the PCB capacitors was foreseeable [23].

Although transformer explosions are rare, they do occur [20,46] and lead to large PCB egress (about 600 galls for a 2 MVA unit). [50 at 425]. However, perhaps more insidious is that PCB units need frequent fluid monitoring which requires sampling, filtering and reprocessing the fluid. [50 at 425]. All these operations lend themselves to opportunities for leaks (a survey by the Solid

Waste Activities Group of the Edison Electric Institute has concluded that 12% of PCB units in utility service develop small leaks and 4% show moderate leaks [25]). These processes are needed in PCB transformers because of the propensity for PCB contamination, and high levels of moisture which can be deleterious to the electric strength. This contamination is the result of the inherent propensity for PCBs to dissolve materials with which they come into contact (gaskets, seals, etc). Although small transformers are sealed, many are equipped with conservators with breathers/desiccators (to deal with thermal expansion) and pressure relief valves [39]. These are potential sources of egress.

To repair a faulty transformer, the owner would often send the transformer to a repair facility. The shipping process occasionally resulted in inadvertent leakage and transportation of PCBs has been identified as one of the highest risk areas for potential spills [39]. The repair shops themselves often had less rigid protocols for the containment of the fluid than the transformer manufacturer, resulting in an increased likelihood of leakage [22]. For example, in a 1970 document, Monsanto acknowledged that service and repair shops generated nearly 1 million pounds of “scrap” PCBs annually, and that “most of this has been dumped or disposed of in streams.” [22, 46] [50 at pages 434-436].

In the mid-1960s, it is documented [20] that Monsanto was supplying significant amounts of PCB fluid (about 1 million lb./year) to the end users of PCB transformers as well as to the OEMs. This implies that these customers were involved with their own fluid handling, service, diagnostics, maintenance and waste processing. With a large proliferation of entities involved, the chances of accidental spills were considerably increased. These non OEM end-users were numerous and included industrial, commercial, transportation, communication, municipal, defense and government sectors.

(3) ***PCBs were released into the environment in connection with disposal.***

PCBs from out-of-service transformers and capacitors may be released into the environment unless special care is taken to prevent such contamination. [50 449, 455]. The EPA has developed a PCB Q & A Manual to provide information on the special practices necessary to prevent PCB-containing capacitors and transformers from creating additional environmental contamination upon disposal. [51]. Additionally, Monsanto's own documents discuss the special measures required to prevent contamination from the PCB-fluid. [35]. However, due to the fact that PCBs required high-temperature incineration for destruction [52], at the life-end of transformers and capacitors, PCBs fluids that were not properly destroyed through incineration were released into the environment via indiscriminate dumping, waste dumps or low temperature incineration.[8] [54]. Consequently, PCBs used in the electrical industry for transformers and capacitors were often released into the environment at the end of the functional life of the transformer or capacitor. [55].

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DSW331019-DSW331031
PCB-ARCH0029298- PCB-ARCH0029319
MONS029168- MONS029177
HARTOLDMON0000499- HARTOLDMON0000691
LEXOLDMON006681- LEXOLDMON006702
PCB-ARCH0054133- PCB-ARCH0054181
HARTOLDMON0000346- HARTOLDMON0000415
WATER_PCB00022761- WATER_PCB00022771
FUN000022- FUN000087
HARTOLDMON0008166-HARTOLDMON0008175
PCB-ARCH0064836- PCB-ARCH0064854
HARTOLDMON0004746- HARTOLDMON0004748
HARTOLDMON0000346- HARTOLDMON0000415
MONS002820- MONS002827
MONS030483- MONS030486
MONS035372- MONS035392
TOWOLDMON0052202- TOWOLDMON0052242
MONS098483- MONS098484
MONS10023- MONS10024
MONS099591- MONS099594
PCB-ARCH0000292- PCB-ARCH0000300
GPFOX00034589
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DFP005464
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PCB-ARCH0076128
PCB-ARCH0296690- PCB-ARCH0296705
PCB-ARCH0102018- PCB-ARCH0102020
PCB-ARCH0030399- PCB-ARCH0030408
PCB-ARCH-EXT0008789
PCB-ARCH-EXT0008789
Kaley Deposition – Colella; November 17, 2011
Kaley Deposition – San Diego; February 19-20, 2019

ATTACHMENT 1

Timeline for the introduction of PCBs and other dielectric fluids.

In an attempt to chronicle the development of dielectric fluids over the second half of the last century, one has to rely on the published literature in a time period where little is accessible from electronic databases. In this context, extensive use has been made of the Digest of Literature on Dielectrics [7] which was published annually, in hard copy, by the National Research Council from 1936 to 1978. This period encompasses most of the important developments made in this area, and starts approximately at the time of PCB introduction. This publication usually included a section on dielectric fluids and often had subsections devoted to oil substitutes and synthetic liquids which are relevant to this study. The liquid dielectric portion of these reviews is dominated, not surprisingly, by the consideration of mineral oils. Only those significant aspects which relate to PCBs and to the introduction of other oil substitutes are highlighted here in order to provide a time line. To put this review into perspective, in the early years, this publication contained about 200 pages *per annum*, but swelled to over 700 pages by 1978.

1936

Mineral oil is the primary dielectric liquid in use, and the technical community is concerned in particular about oxidation stability. Nothing very significant appears on alternative liquids.

1937/38

Reference to the introduction of non-flammable chlorinated hydrocarbons as capacitor impregnants.

1938/39

There was significant activity in identifying non-petroleum and synthetic substitutes for mineral oil. The Digest starts a specific category relating to substitute and synthetic dielectric fluids. In this context the materials cited as useful included: trichlorobenzodifluoride, halogenated benzotrifluoride, chlorinated biphenyl mixed with benzyl choride, mixtures of trichloro- tetrachloro- and pentachloro-isopropylbenzene, mixtures of oils of high molecular weight formed by polymerization, chlorinated aryl compounds with additives, hydrogenated aromatic hydrocarbons.

1939/40

Major review included the properties of halogenated hydrocarbons including mixtures with other fluids. Numerous papers published on synthetic substitutes for transformer oil with an emphasis on mixtures including: trichlorobenzene mixed with pentachlorodiphenyl, trichlorobiphenyl mixed with vegetable oil, and fluids resulting from blends of di- & tetra-chlorobenzotriflouride, chlorinated isopropyl benzene and chlorinated ethylbenzene.

Introduction of vegetable oils as mineral oil substitutes; particularly soy bean oil and castor oil.

<u>1941</u>

Continued development of ASTM standards for insulating liquids and insulating structures using chlorinated hydrocarbons.

Significant patent activity relating to the improvement of transformer oil using antioxidants and stabilizers. Significant patent activity on the use of mineral oil substitutes – particularly mixtures of chlorinated fluids. Trade Names for PCBs introduced e.g. Pyranol® and Clophen® (European).

<u>1942</u>

Continued emphasis on oil sludging and on oil reclamation.

Stability of cellulose impregnated with chlorinated compounds attracting attention.

<u>1943</u>

Patent and publication activity on the introduction of chlorinated synthetic liquids in Germany and Russia.

<u>1944</u>

Nothing very relevant or significant cited

<u>1945</u>

Introduction of anthraquinone as a chemical stabilizer for systems containing chlorinated liquids to inhibit corrosion and leakage current.

Introduction of silicone fluids (for applications as a less flammable substitute for mineral oil) documented and patent issued.

Degradation of chlorinated capacitor impregnants under thermal and electrical stresses identified, and continued discussion of corrosion inhibition in PCBs.

<u>1946</u>

Nothing very relevant or significant cited

[1947-49 unavailable]

1950/51

Substantial patent activity primarily relating to PCB and silicone fluids. In particular, those referring to silicones fluids herald the increased interest, use and acceptability of these synthetic alternatives. This may be gauged from a partial listing:

Goodwin, US 2506513, Hexaorganodisilapropanes
Daudt, US 2550003, Copolymerization of organosiloxanes
Wormuth, US 2552247, Organopolysiloxanes
Francis, US 2573426, Silcarbane polymers
British Thomson-Houston, UK 653247, Substituted polysiloxanes

1952

Stabilization of trichlorobenzene or pentachlrobiphenyl with oxygenated aluminum compounds (e.g. aluminum hydroxide)

Extensive series of studies of Japanese origin relating to PCB compounds and their mixtures with conventional mineral oil. The papers concern changes in flash and fire points and the composition of pyrolysis gases as well as physical data. Collectively, this body of literature represents data of unusually broad scope relating to chlorinated hydrocarbons.

1953

Continued documentation by the Japanese of the electrical, physical and thermal properties of chlorinated hydrocarbons; specifically chlorophenylcyclohexane and chlorophenyldecahydronaphthalene.

Two different instances of the introduction of fluorochemical fluids [e.g. $(C_4F_9)_3N$] which are chemically inert, non flammable and thermally stable up to 400°C

A US patent claims that fluorine containing siloxane liquids are thermally stable and may be used as substitute dielectric fluids. A further patent discloses mixtures of sulfolanes and aromatic sulphones as useful dielectric liquids.

Three different UK patents were issued for different synthetic dielectric liquids and Dow Corning received a patent for the use of liquid organosilicone copolymers as liquid insulants.

Further development of PCB mixtures is documented.

1954

PCBs introduced into service in transformers in the Czechoslovakia

1955

Synthetic liquids introduced in Poland.

Description of chlorofluorocarbon oils (e.g. Florolube®) with electrical properties as good as or exceeding mineral oil.

Completely fluorinated liquids introduced for communication transformers permitting reduced size and weight and allowing operation to 200°C

1956

Comparisons published of the gassing properties of PCB, silicone fluids and conventional mineral oil.

Several reviews of the use of PCBs in transformers and capacitors. Documentation of problems associated with low temperature operation of PCBs.

Consideration of the low temperature operation of silicone liquids with special reference to gas formation under arcing conditions.

[1957-59 unavailable]

1960

Documentation of the electrical breakdown of silicone fluids for frequencies up to 10 MHz.

Usual review of Liquids not included in 1960 – deferred to 1961 edition

1961

A French patent claimed the use of aryl aliphatic hydrocarbons as insulating oils.

Numerous papers relating to the use of PCB and other synthetic liquids and their mixtures as capacitor impregnants.

1962

Continued discussion of oil properties and those of materials already designated as replacements such as non flammable chlorinated systems, high temperature resistant silicone oils and perfluoro compounds. The increased interest in synthetic dielectrics was said to be due to the increasingly arduous conditions in which electric equipment was required to operate. This discussion is also active in Europe where, in Germany, the use of fluorocarbons is advocated on the basis of their favorable electric characteristics. Similarly a French contribution provides the various possibilities and characteristics of silicones for insulation purposes. In terms of applications, a stabilization

method is advanced for the use of silicone fluids as capacitor impregnants through the use of up to 5% of a ketone such as anthraquinone.

1963

Publications on dielectric liquids of all sorts (inc. PCBs) become much more numerous and reflect a more fundamental, phenomenological and academic approach.

Life testing of PCB capacitors and several further investigations of dielectric loss phenomena in chlorinated biphenyls.

Comparisons of oil, PCB, silicone fluids and fluorocarbons for transformer operation at a NEMA-IEEE meeting were presented by Howe and Kingsley. The limitations of each fluid were reviewed and the material properties which relate to the operation of liquid-filled transformers at higher temperatures

1964

Continued discussion of the effect of the chemical composition of Askarals on their electrical properties when used as a capacitor impregnant.

1965

Comparison of the properties of PCBs with those of diphenylchorides with the conclusion that the higher price is offset by the capabilities and compaction possibilities for capacitors.

Monsanto patent on polyphenyl ether as a high temperature dielectric, and UK and German patents and papers on alternative dielectric fluids having high temperature stability.

Several new high permittivity liquids investigated (including partially fluorinated esters and fluorosilicones) for capacitor applications.

Documentation of the properties of fluorocarbon liquids relevant to their use as electrical insulation and heat transfer media.

1966

Nothing very relevant of significant cited. Most of the emphasis is becoming shifted towards the understanding of the mechanisms of conduction and breakdown in dielectric fluids.

1967

Comparison of the dielectric losses of silicone oil in comparison with conventional mineral oils as a function of temperature, frequency and electric stress. For mineral oil, both the ionic and dipole

losses increase with the aromatic content of the oil, and the ionic loss was found more sensitive to viscosity than the dipole loss. A peculiar type of absorption loss that increased with decreasing temperature was found to be characteristic of silicone oils below -50°C.

1968

PCBs used with a polypropylene-paper combination of solid dielectric to provide improved performance in capacitors.

A comparison of the properties (electrical, chemical, rheological) of a range of dielectric liquids for use as oil replacements published together with data on applications.

1969

Impulse strengths of fluorocarbon liquids documented for application in specialized environments.

1970

Further development of polypropylene/trichlorodiphenyl capacitor technology by several organizations, including the consideration of the dynamic loss phenomena.

1971

Nothing very relevant or significant cited

1972

Nothing very relevant or significant cited

[1973 Unavailable]

1974

Comparisons of the dielectric strength of PCB impregnated capacitor structures under various forms of voltage application (AC, DC, and impulse) and cross-referencing with mineral oil.

Gassing characteristics of silicone fluids documented.

Swelling studies undertaken for a range of capacitor impregnants.

Effects of water contamination in silicone fluids investigated.

More stringent OSHA regulations announced.

Further considerations of the dynamics of loss for PCB impregnated polypropylene capacitors.

[1975 Unavailable]

1976

The environmental concerns of PCB are viewed in more urgent and forceful terms.

Accelerated effort to investigate substitutes for PCBs.

Discussion of the true meaning and relevance of non-flammability.

1977

Continued effort on the search for other solutions to replace PCBs in liquid-filled apparatus (mainly transformers and capacitors).

Exploration of phenyl-methyl silicone fluids in comparison with dimethyl silicone liquids.

Acceleration of the consideration of askarel-to-silicone retrofill issues.

1978

Edisol® (non-toxic and biodegradable) advanced as a PCB substitute, and phthalate esters considered as possible substitutes for PCBs.

Fire safety for insulating liquids reviewed.

Highlighting of the need for better flammability testing.

Highlighting of the importance of thermophysical properties as well as the electrical properties of PCB substitutes.

CIGRE becomes involved through two publications which cite the types of Askarels which are particularly persistent in nature.

New analytical tests advanced for testing non-PCB dielectric fluids in power factor correction capacitors.

Timeline Summary

► The introduction of PCBs as a non-flammable alternative for mineral oil occurred in the 1930s and was the material of choice for transformer applications in fire-sensitive locations and for power capacitors until the early 1970s – see Figure 1.

► PCBs were not the only candidates for use as synthetic insulating fluids. It is clear that a range of other materials were being researched as early as 1938.

► Vegetable oil alternatives were being studied as early as the late 1930s.

► PCB patenting activity was very active in the 1940s to establish the material.

► Indications of the toxicity of PCBs were known at least as early as 1944 [6]

► The 1940s and 1950s saw the refinement of PCB fluids (and mixtures of liquids) to improve the stability, the leakage current and the corrosive action.

► By 1945 silicone fluids were available as less flammable substitutes for mineral oil.

► By the early 1950s fluorochemical fluids were available as non-flammable oil substitutes, although they were (and still are) expensive, and required design changes.

► The 1950s saw activity to develop a range of other synthetic fluids as transformer oil substitutes. This culminated later in the introduction of, for example, materials such as Midel® 7131 (*see later*)

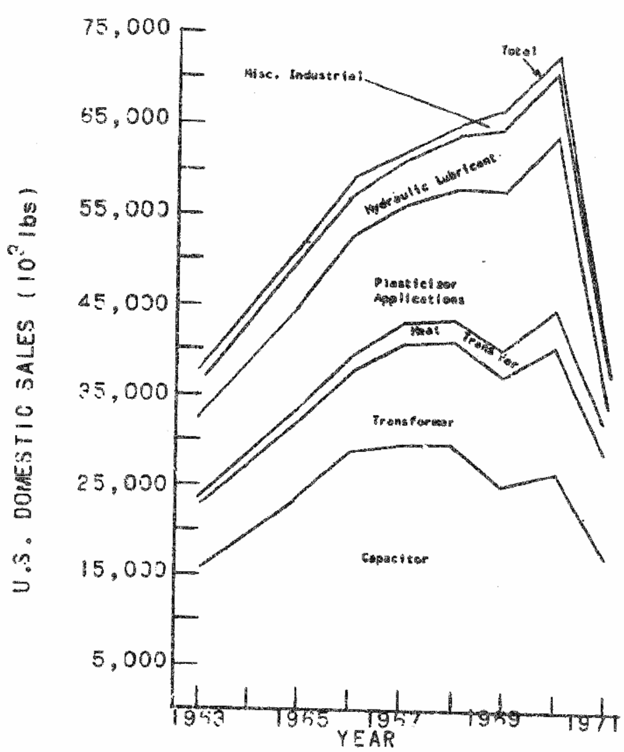


Figure 1. US Domestic sales of PCB materials [11]

► The development of synthetic liquids plateaued in the 1960s and the research community focused more on unraveling the fundamental physical and chemical mechanisms which underlie conduction and breakdown in liquid insulants.

► By the mid 1970s, the environmental impact of PCBs was more widely recognized, and this resulted in a renewed effort to qualify substitutes and to address the retrofill issue.

► In 1978, less flammable oil substitutes were introduced such as Edisol® and Midel® 7131 (a synthetic ester-based transformer fluid which is a fire-resistant, biodegradable, moisture tolerant, oil substitute).

Fluid	Commentary
Mineral Oil	• Original and preferred dielectric fluid throughout the 20th century, continuing to present day

Polychlorinated biphenyls	● Introduced in about 1929, and quickly commercialized (1930) as a synthetic mineral oil substitute which was non-flammable. The higher permittivity made it also attractive as a capacitor impregnant. ● Significant patent filing in the early 1940s ● Health effects recognized in the mid 1940s ● Banned worldwide in the 1970s
Vegetable oils	● Introduced in the late 1930s ● Refined and saw widespread commercial introduction in the 1990s following the PCB ban
Other synthetic oil substitutes (inc. oils of high Mol. Wt.)	● Introduced in the late 1930s ● Adopted early as capacitor fluids ● Adopted as transformer oil substitutes in the late 1970s immediately following the PCB ban
Silicone fluids	● Introduced and patented in the mid 1940s ● Extensive patent activity in the early 1950s ● Progressive commercial introduction continuing to present day
Fluorocarbons	● Introduced and patented in the early 1950s ● Commercial introduction for a transformer in 1955 ● Very limited penetration because of extreme cost and generation of greenhouse gas

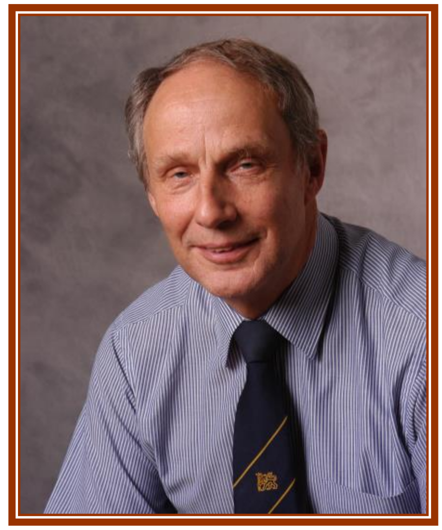
Table 2. Encapsulated view of the use of dielectric insulating liquids in power equipment (principally transformers and capacitors)

Table 2. has attempted to encapsulate this information when ordered by the major fluid types. However, in presenting the material in this form, many important initiatives and attributes are suppressed. This is because it is clear that the development of the commercial products was characterized in large measure to the introduction of mixtures of fluids and to the use of inhibitors and stabilizers to suppress some of the less desirable attributes and to extend longevity. The dates provided in Table 2, and, indeed, in the timeline above can only be regarded as very approximate. They are based on publications that will usually lag (sometimes substantially) events due to publication delay and commercial interests.

ATTACHMENT 2

CURRICULUM VITAE

J. Keith Nelson



Personal

Place of Birth: Oldham, UK
Married: 2 children
Health: Excellent

Current Appointment (since 2009)

Professor Emeritus,
Rensselaer Polytechnic Institute, Troy, NY, USA

Employment History

2001-09	Philip Sporn Professor of Electric Power Engineering
2002	Visiting Professor *[Sabbatical leave]* University of Leicester, UK
1987 – 01	Chairman, Department of Electric Power Engineering Rensselaer Polytechnic Institute
1993	Visiting Research Officer *[Sabbatical leave]* National Grid Company, Leatherhead, UK
1982-87	Professor of Electric Power Engineering (Tenured), Rensselaer Polytechnic Institute
1979-82	Research Manager, General Electric, Corporate Research and Development
1978-79	Reader in Electrical and Electronic Engineering (Tenured), University of London, UK
1969-78	Lecturer in Electrical Engineering (Tenured), Queen Mary College, London, UK

Degrees

B.Sc.(Eng) in Electrical Engineering [with First Class Honors],
University of London, 1965
Ph.D. in Power Engineering,
University of London, 1969

Non-degree preparation

Graduate Apprenticeship: Eastern Electricity, UK, 1962-66
Chartered Professional Engineer: Reg. # 236275, 1972
FAA Certified Commercial Pilot (AMEL #3475560)
General Electric Professional Engineering Management Course, 1980.

Consulting

General Electric [several divisions]
Electric Power Research Institute
United Nations
Long Island Lighting Co.
Doble Engineering Co.
Bechtel
Intermagnetics General Inc.
British Columbia Hydro
Consolidated Edison
National Inst. of Stand. & Tech.
Fleetguard Inc.
W.L. Gore & Ass.
Cooper Power Systems
US Foreign Relations Coordination Unit
American Electric Power
United Technologies
Asea Brown Boveri
Los Alamos National Laboratory
Advanced Electron Beams
British Petroleum
Medtronic
ORC International [many assignments)
National Railroad Corp.
Analogic

Plus numerous firms of attorneys

Publications

Author (or coauthor) of over 250 technical papers, book chapters or patents (separate listing available). Recent publication of J.K. Nelson, "Dielectric Polymer Nanocomposites", Springer, 2010 – the first specialist book on nanodielectrics.

Scientific and Professional Activities

Institution of Engineering & Technology: Corporate Member, 1972**;** **Fellow**, 1986.
Institute of Electrical and Electronic Engineers: Senior Member, 1979, **Fellow** 1989

- Administrative Committee of the IEEE Dielectrics and Electrical Insulation Society, IEEE, 1983-88, 1991-2008 (VP [Technical] 1991-2, VP [Admin] 1993-4, **President** 1995-6)
- Program Committee for NAS/NRC Insulation Conference, 1979-83
- Board and Executive Committee (**Chairman** 1988-90) of the IEEE CEIDP Conference, 1990 - present
- Member of the IEE Professional Group Committee on Transmission and Distribution Plant,

1974-77

- **Chairman** of the IEEE DEIS Education Committee, 1983-91
- IEEE Educational Activities Board, 1985-88, 2011
- CIGRE US national expert and member of the Working Group 1991-12/15-02 on flow electrification
- IEEE PES subcommittee on digital analysis of partial discharges (1987-98)
- IEEE PES subcommittee on High-voltage testing techniques (1995-99)
- IEEE DEIS Technical Committee S-32-11 on Gaseous Dielectrics (1987-98)
- IEEE Technical Activities Board Technical Activities Advisory committee (1986-87)
- IEEE TAB Meetings Council, 1996
- IEEE DEIS Membership Development Committee, (**Chairman**, 1997- 2009)
- IEEE New Technology Directions Committee, 1996 - 2006
- Refereeing panels for: IET, IEEE (several Societies), Inst. of Physics, NSF, and J.of Electrostatics
- ABET Program Evaluator, 2007 - present
- Guest Editor: DEIS Transactions, 2005, 2008 and 2014
- IEEE DEIS Awards Committee, 2009 - present
- IEEE TAB/PSPB Products and Services Committee 2010
- Executive Committee and Board of Governors, IEEE Region 1. 2010-13
- **Director**: Institute of Electrical & Electronics Engineers, 2011-12
- IEEE DEIS Schenectady Chapter, **Founding Chairman**, 2012
- IEEE Governance Committee 2013-15
- IEEE TAB Management Committee, 2013-15
- IEEE Distinguished Lecturer, 2007 - present
- IEEE Foundation Signature Program Evaluation Committee, 2017 - 2019

Honors and Awards

- Eastern Electricity National Scholarship, 1962
- IEE Snell Premium, 1972
- J.R. Beard Award, 1972
- British Council Research Worker's Award, 1974 and 1976
- Royal Society Award, 1976

- General Electric Patent Award, 1983
- DEIS Fellowship, 1983
- Japan Soc. Prom. Sci. Fellowship, 1987
- IEEE Whitehead Memorial Lecturer, 1993
- Edison Electric Institute Power Engineering Educator Award, 1994
- American Association for Non-destructive Testing Fellowship Award, 1997
- IEEE Forster Distinguished Service Award, 1998
- Millennium Medal, IEEE, 2000
- Appointed to the Philip Sporn Chair, Rensselaer Polytechnic Institute, 2001
- Hans Tropper Memorial Lecturer, 2002
- Outstanding Professor Award, Rensselaer Polytechnic Institute, SoE, 2007
- Ziyu Liu Memorial Lecturer, 2012
- Inuishi Memorial Lecturer, 2014
- Albert Nelson Marquis Lifetime Achievement Award, 2017

Citations

Who's Who in America. 1984 - present
American Men and Women of Science. 1991 - present

Teaching Experience

Courses have been given at all undergraduate and graduate levels as well as specialized industrial short courses. Subject areas include:

Physical Electronics
Electric Power Engineering (several specializations)
Gaseous Electronics and Insulation Science
High Voltage Engineering
Nanodielectrics
Transformer Design
Electromagnetic Fields
Engineering Modeling and Design
+ several basic electrical engineering courses.

Numerous MS, Ph.D. and D.Eng. supervisions in both the UK and the USA

Research Experience

Responsible for the acquisition of funding and program management of research activity in the following areas:

Transient phenomena in HT Superconductors
Dielectric phenomena
Insulation design for power equipment

Electrokinetic effects in flowing fluids
Electrostatics
Fundamental gas discharge physics
Development of computer-based diagnostic instrumentation for rotating machines
Power system distributed generation
Nanodielectrics

Large-scale computer simulation in connection with some of the above.

As previous departmental head, spearheaded initiatives in power electronics, power quality and power system component modeling.

Extensive prior experience as Manager of the Electric Field Technology Programs at the General Electric Corporate R & D Center (*now Global Research Center*).

Previous experience in managing high power testing laboratories (HV and SC)

Extra Curricular Activities

Vestry of St. Stephen's Episcopal Church (1987-91, 2004-07)
Flying (FAA certified commercial pilot: AMEL)
Sailing (both ocean-going and dinghy)
Certified Scuba Diver
Squash

PROFESSOR J. KEITH NELSON

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ATTACHMENT 3

SUPPLEMENTARY INFORMATION RELATED TO THE LEGAL CASE

A. Recent prior involvement in litigation in electric power issues by Dr. Nelson

The author has been involved with several cases over the years which have involved appearances in court or at depositions as an expert witness. The most recent may be summarized as:

(i) May 2016: Appearance in the matter of an arbitration under the provisions of the Arbitration Act (Alberta) and the provisions of the Power Purchase Arrangement for Keephills under Section 96(1) of the Electric Utilities Act (Alberta) between: Transalta Generation Partnership vs. Enmax Energy Corp. & Balancing Pool

(ii) June 2019 : City of San Diego, et al. v. Monsanto Company, et al.

B. Remuneration

Dr. Nelson is being compensated at an hourly rate of $250 for analysis and preparation of the expert report. The hourly rate during depositions and trial testimony is also $250.